32

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CONTENTS

Tasmanian Seaweeds for the Edible Market

J. Craig Sanderson and R. Di Benedetto

ABSTRACT

Total world wide trade in edible seaweeds is presently over Aus$1 billion, mainly amongst Japan, Korea and China, of which Japan probably has the greatest proportion of trade.

Trade is mainly in three varieties of seaweed:- Nori (Porphyra spp.), Kombu (kelps) and Wakame (Undaria spp.). The value of other unspecified seaweeds imported by Japan in 1986 from a variety of countries was Aus$3 million or 5% of the total value of Japans seaweed imports.

Tasmania has an abundance of seaweed species, many of which are similar to those utilized elsewhere. A hypothetical costing of mariculture of various seaweeds here in Tasmania demonstrates the potential to supply seaweeds at competitive prices to the edible market.

A selection of samples sent to Japanese trading companies resulted in limited interest. A lack of understanding of the requirements of the Japanese edible market cannot be discounted. Any future marketing requires the direction of somebody with expertise and an understanding of the market in this area.

Analyses of arsenic concentrations in Tasmanian seaweeds gave low values. This consistent with Tasmania's claim that its waters are comparatively free from pollution.

Expansion of market interests in seaweeds for alginate and agar industries remains a possibility.

INTRODUCTION

The aim of this preliminary report is to determine the potential for a Tasmanian seaweed industry based mainly on the exportation of edible species. To a large extent this report was initiated by the interest in Tasmanian seaweeds expressed by two Japanese phycologists, Jiri Wein and Etsuko Saki who visited Tasmania in 1986. They were researching a book on edible seaweeds of the world and described the Tasmanian seaweed flora as 'particularly rich in bulk and superbly edible species'.

The report therefore provides the following:-

1. literature references to edible seaweeds
2. A species list of Tasmanian seaweeds and their distributions determined from herbarium specimens lodged with the Tasmanian State Herbarium.
3. Results of collection trips conducted at sites around the state to further distribution records and assess quantities available.
4. An assessment by the JETRO (Japanese External Trade Organization) of trial shipments of selected Tasmanian seaweeds.

5. A summary of the current state of World Trade in edible seaweeds.
6. The results of analyses of the arsenic content of Tasmanian seaweeds.

1.1 Seaweeds - What are they ?

Most seaweeds are attached algae that grow on rocky coasts from the intertidal zone to depths of 20-30 m. They range in size from microscopic filamentous plants and paint-like crusts to kelps up to 30 m long and with a mass of 100-299 kg.. There are three main groups: the green algae (Chlorophyta), the red algae (Rhodophyta) and the brown algae (Phaeophyta). These divisions are quite dissimilar in terms in terms of their photosynthetic pigments, physiology, chemical composition, morphology and methods of reproduction.

The southern Australian region including Tasmania is one of the richest areas for species of macroalgae in the world. Womersley (1980) estimated there to be 94 different species of Chlorophyta, 191 species of Phaeophyta and 725 of Rhodophyta. Despite this great diversity, there is very little utilization of seaweeds in southern Australia. Michanek (1975) in a comprehensive appraisal of the seaweed resources of the world for the Food and Agriculture Organization of the United Nations, ranked Tasmania high with Scotland, Norway, Japan, Nova Scotia, Chile and the Pacific Coast of Canada and USA, all characterized by rather cold waters, comparatively rich in nutrients and rocky shores.

1.2 Seaweeds as a food

By far the greatest consumers of algae are the Japanese, Koreans and Chinese. Annual consumption of macroalgae by the Japanese averages 1.5 kg per person (see Table 1) and may comprise one or a combination of 21 varieties of seaweed (Chapman & Chapman 1980, Araski 1983). The main seaweed products eaten in these three countries are '**nori**', '**kombu**' and '**wakame**'.

Species	Per capita consumption g/year
Aonori, hitoegusa (*Enteromorpha sp.,Monostroma nitidum*)	31
Hiziki (*Hizikia fusiforme*)	20
Kombu (*Laminaria sp.*)	320
Wakame (*Undaria pinnatifida*)	972
Asakusa-nori (*Porphyra sp.*)	208
Mozuka (*Nemacystus decipiens*)	30
Total	**1,581**

Table 1. Annual per-capita consumption of seaweeds by the Japanese (1969-71).

1.21 Nori

Nori is manufactured from selected species of the red algal genus *Porphyra*. In Japan there are ten species of *Porphyra* but only a few are suitable for nori. *Porphyra tenera* formerly constituted most of the product but *P. yezoensis* has gradually taken its place. Fresh *Porphyra* has the appearance of a flat membranous, green-pink to purple-black plant that is commonly 20-30 cm in circumference and a couple of cells thick. The fronds are harvested by hand from nets that have previously been artificially seeded. Once harvested the plants are cleaned and chopped into small pieces. The slurry is then poured onto a plastic net or a bamboo mesh so that the chopped fragments fuse to form thin sheets. These sheets are then dried together with the framework in a hot air chamber, sheets are removed, packed according to apparent quality and are marketed in wrapped packets of sheets. This form of nori is the most common and is known as hoshi - nori. Another form of nori, called aonori is produced from *Ulva* sp. (sea lettuce, 90 % of product), *Enteromorpha* and *Monostroma*. These algae are also cultivated on a commercial scale. Nori is used in a variety of dishes but is best known for its use in *sushi*.

1.22 Kombu

Although kombu is a general name referring to all species of kelp, seaweeds of the brown algal genus *Laminaria*. are most commonly eaten. The principal species being *Laminaria japonica*, *L. religiosa*, *L. coriacea* and *L. angustata*. These large kelps, 1-3 m. long are dried in the sun soon after harvest or sometimes in a hot air drier, depending on the weather. The kombu product thus obtained is collectively called suboshi - kombu. The kombu blades from each fishing ground have individual qualities and each is manufactured by a characteristic procedure. Kombu is used as a vegetable, as a soup stock, as a seasoning and as a snack food.

1.23 Wakame

Wakame is the dried blades of the brown alga *Undaria pinnatifida* . The plants commonly up to 1 m. in height. consists of a leafy thallus on a short ($<^1/_3$ of total length) convoluted stipe. The stipe, in maturing plants functions as the spore producing part of the plant. Like kombu, timing of the harvesting periods are critical to maximize product quality. Previously, kombu and wakame have been harvested from the sea floor, now however, artificially cultivated plants are the greater source of product.

For preparation of wakame, plants can be dried in the sun, this is known as suboshi - wakame. Plants produced in this fashion however, often fade and soften during storage.

To remedy this, dried plants are treated with ash and the resulting product is known as haiboshi - wakame. In this way plants 'retain their green colour for a longer period and are fairly elastic to give a pleasant flavour upon chewing' (Nisizawa et al 1987). In recent years, about 50% of the market for the dried product has been replaced by a salted, wet form. Wakame is commonly utilized in *miso* soup and with soups and noodles in general.

1.24 Nutritional value of Seaweeds.

The greater proportion of seaweed is made up of carbohydrates. Non fibrous carbohydrates including alginate, fucoidan, mannitol and laminaran can in some instances reach up to 70 % of a seaweed on a dry weight basis but are difficult to digest for humans except by enteric microbes. Digestibility of 70 % has been demonstrated for Asakusa-nori (*Porphyra tenera)* of carbohydrates and proteins however, the greater digestibility is due to the action of intestinal bacteria. Arasaki & Arasaki (1983) suggest seaweeds are good diet foods because while little is digested, they are still satisfying.

Biological activity has been shown for some macroalgal carbohydrates. Fucoidan is known to show antihyperlipermic and blood coagulant activities and alginate has bought about antitumour effects and lowered cholesterol and blood pressure levels in rats.

Other constituents are fucosterol (prevents thrombosis), eicosapentaenoic acid (EPA, particularly in nori; effective against arthrosclerosis) and essential trace elements as well as common indispensable minerals. Vitamin levels in nori (high in vitamins A & C) are comparable to spinach, while levels in kombu are one half to one tenth these levels with the exception of vitamin B_{12}. Most vegetables lack this vitamin. Raw or sun dried seaweed products seem useful in supplementing B-group vitamins (Nisizawa 1987).

More details concerning the nutritional content of seaweeds can be found in articles by Nisizawa (1987), Arasaki & Arasaki (1983) and Chapman & Chapman (1980).

1.25 Taste and Flavour

It was while eating tofu in a broth made with kelp that Professor Kikunae Ikeda at Tokyo University in 1908 he reasoned that there was an element in the broth that made it seem delicious, he then went on to isolate glutamic acid (found also to a lesser degree in many vegetables, cheese and other seafoods), a significant moment in food research. This aspect of taste is considered accessory to the basic units of taste, sweet, sour, salty and bitter - a fifth dimension - since named *umami*. Other key elements to *umami* have been identified as inosinate (in fish) and guanylate (mushrooms, pork, beef and chicken).

Whether this aspect of taste represented as it is in seaweeds has a place in Western culture, is yet to be realized.

1.3 Food products from seaweeds

Seaweeds are the source of several commercially useful phycocolloids (algal polysaccharides), uses of which range from ice cream stabilizer to beer foam stabilizer to frozen pie fillings, culture mediums and printers ink. These polysaccharides are unique to the algae and generally form part of the cell wall matrix. They are thought to aid in buffering the plants against physical damage and the ability of the polysaccharides to imbibe water provides protection for intertidal plants against desiccation. The main commercial polysaccharides extracted from algae are alginates (brown algae), agaroses and carrageenans (both extracted from red algae, see Figure 1). Uses of these products depends on the thickening or gelling properties displayed by the extracts. Desirable properties may be obtained by mixing different types.

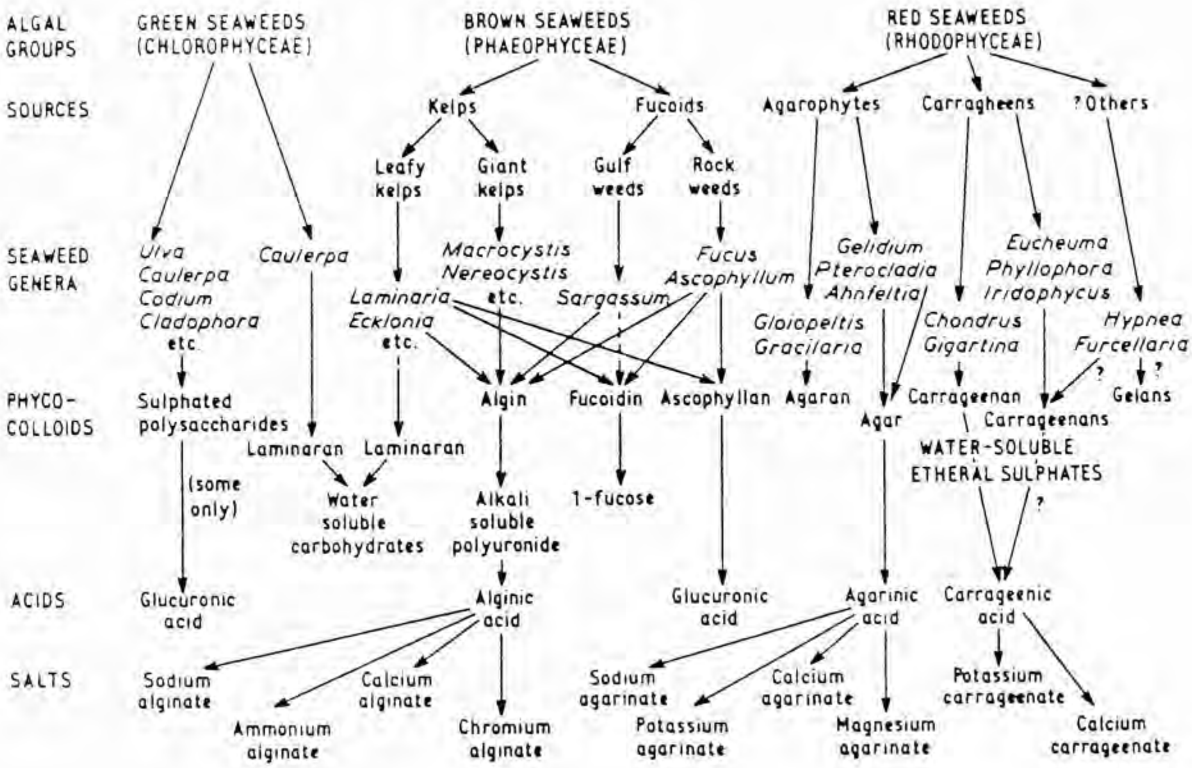

Figure 1. Diagram giving a indication of the sources and interrelations of the three groups of phycolloids (algal polysaccharides) (Tseng, 1945 a).

2 MACROALGAL GENERA UTILIZED WORLDWIDE

2.1 Edible algae

A review of the recent literature reveals a total of 34 different species of Chlorophyta, 65 species of Phaeophyta and 175 Rhodophyta are eaten world-wide (Appendix 1). The following table shows which genera and the countries in which they utilized.

Genus	Importance	Where presently utilized
		CHLOROPHYTA
Caulerpa	***	Indonesia, Japan, Phillipines, Taiwan, China, Hawaii
Chaetomorpha	*	Phillipines, Taiwan, China,Indonesia
Codium	**	Korea, Japan, Hawaii, Indonesia
Enteromorpha	***	Japan, Taiwan, USA, China, Tobago, Hawaii, Malaya
Monostroma	**	Japan, Taiwan
Prasiola	*	Japan, Mexico
Ulva	***	Hawaii, Japan, Korea, West Indies
Nostoc	*	Japan, Sth America, China, Malaysia
		PHAEOPHYTA
Alaria	*	USA, Japan, Scotland, Orkney Is.s, Iceland, Korea, Alaska, Greenland
Analipus	*	Japan
Arthrothamnus	*	Japan
Ascophyllum	*	USA
Chnoospora	*	Vietnam, Guam
Chorda	*	Japan
Chordaria	*	Japan
Cladosiphon	*	Japan
Durvillaea	*	Chile, Argentina
Dictyopteris	*	Hawaii
Ecklonia	**	Japan, China, Korea
Eisenia	**	Japan
Endarachne	*	Japan
Fucus	**	W Europe, USA, Alaska
Heterochordaria	*	Japan
Hizikia	***	Japan, Korea, China
Hydroclathrus	*	Phillipines, SE Asia
Kjellmaniella	*	Japan
Laminaria	***	Japan, USSR, Nth America, Alaska, Korea, Brittany, W. Europe
Macrocystis	*	California
Nemacystus	*	Japan
Padina	*	Sri Lanka
Petalonia	*	Japan
Pleurophycus	*	USA
Postelsia	*	California
Sacchorhiza	*	Cold Atlantic
Sargassum	***	Japan, China, Korea, Hawaiian Islands, SE Asia
Scytosiphon	*	Japan
Tinocladia	*	Japan
Turbinaria	*	Indonesia
Undaria	***	Japan, Korea, China

continued..

Genus	Importance	Where utilized
		RHODOPHYTA
Acanthophora	*	Indonesia, Caribbean
Agardhiella	*	Phillipines
Ahnfeltia	**	Hawaii,USSR, Japan
Asparagopsis	**	Hawaii, Indonesia, Java
Bangia	*	Japan, China, Taiwan
Bostrychia	*	Burma
Caloglossa	*	Burma
Camplyaeophora	*	Japan
Carpopeltis	*	Japan
Catenella	*	Burma
Chondrus	**	Japan
Corallopsis	*	Indonesia
Dermonema	*	Botel Tobago Is
Dignea	*	Japan, SE Asia
		Bermuda, Phillipines
Euchema	***	Antigua, Barbados, China, Japan, West Florida &
Gelidiopsis	**	Indonesia, Phillipines
Gelidium	***	Japan, China, Korea
Gigartina	***	Japan, Iceland, Nth America
Gloiopeltis	**	Japan, Vietnam, China, Taiwan
Gracilaria	***	Hawaii, China, Sth Africa, Phillipines, Vietnam, California, Java, Gulf of Mexico, Cuba, Indonesia, Ceylon, Thailand, England, Wales
Grateloupia	*	SE Asia
Griffithsia	*	Vietnam
Gymnogongrus	**	Hawaii, Indonesia, Japan
Halosaccion	*	USSR
Haliseris	*	Hawaii
Halymenia	*	SE Asia
Hypnea	*	Indonesia, China, Hawaii
Iridaea	**	Scotland, Iceland
Laurencia	**	USA, W Europe, Scotland, Indonesia, Hawaii
Liagora	*	SE Asia
Meristotheca	**	Japan
Mesogloia	*	Japan
Naias	*	Hawaii
Nemalion	*	Japan, Italy
Palmaria	***	E USA, E Canada, Alaska, Brittany, Ireland, Iceland, W Europe, USSR, Mediterranean
Polyneura	*	California, Phillipines
Porphyra	***	Europe, Hong Kong, Scotland, Ireland, Wales, China, Korea, USA, Alaska, Chile, Japan, British Columbia
Rhodymenia	*	Europe, Nth America
Sarcodia	*	Japan, Indonesia
Scinaia	*	SE Asia

Table 2. Edible seaweeds by genus and countries where used.

2.2 Agar Bearing Seaweeds

Table 3 shows genera of agar bearing seaweed, where they are utilized and an indication of their relative importance.

Genus	Importance	Where utilized
Acanthopeltis	**	Japan
Ahnfeltia	**	Japan, Hawaii,USSR
Brongniartella	*	Cuba, Puerto Rico
Bryothamnion	*	Cuba, Puerto Rico
Camplyaeophora	*	Japan
Ceramium	**	Japan
Dignea	*	Japan, SE Asia
Enantiocladia	*	Cuba, Puerto Rico
Gelidiella	**	Japan
Gelidiopsis	**	Indonesia, Phillipines
Gelidium	***	Japan, S. Africa, Cuba, Mexico, California, China, Indonesia, Taiwan, Korea, Morocco, Portugal, Chile
Gigartina	*	Japan
Gloiopeltis	*	?
Gracilaria	***	Japan, W. Florida, Bermuda, New Zealand, Hawaii, Azores, Cuba, Puerto Rico, Vietnam, California, Malaysia, Sth Africa, Phillipines, Ceylon, China, Senegal
Gracilariopsis	*	Cuba, Puerto Rico
Grateloupia	*	Japan
Gymnogongrus	*	Cuba, Puerto Rico
Hypnea	*	Brazil, Senegal, Phillipines, Cuba
Peyssonnelia	*	Angola
Pterocladia	***	Australia, New Zealand, Azores, Japan, N America, W Florida, Bermuda.
Sarconema	*	India
Spyridia	*	India
Suhria	*	Sth Africa

Table 3. Agar bearing seaweeds by genus and countries where used.

2.3 Carrageenan Bearing Seaweeds

Table 4 shows genera of carrageenan bearing seaweeds, where they are utilized and an indication of their relative importance.

Genus	Importance	Where utilized
Aeodes	*	S. Africa
Chondrus	***	E. USA, Iceland, France, Japan, China, Canada
Delisea	*	?
Dumontia	*	?
Endocladia	*	?
Euchema	***	W. Florida, Bermuda, Japan, E.Africa, Phill., China
Furcellaria	**	Denmark, Russia, Canada
Gigartina	***	Mexico, Ireland, Sth Africa, Sth Europe, Morocco, Chile
Hypnea	**	Japan, Cuba
Iridea	*	SE Asia
Iridophycus	*	?
Pachymenia	*	Sth Africa
Phyllophora	**	Black Sea
Rhodoglossum	**	Japan ?
Tichocarpus	*	USSR
Yatabella	*	?

Table 4. Carrageenan bearing seaweeds by genus and countries where used.

2.4 Alginate Bearing Seaweeds

Table 5 shows genera of alginate bearing seaweeds, where they are utilized and an indication of their relative importance.

Genus	Importance	Where utilized
Alaria	*	Ireland
Arthrothamnus	*	Cold Nth Pacific
Ascophyllum	***	Norway, UK
Cystophyllum	*	India
Cystoseira	*	Mexico, Nth America
Durvillaea	**	Chile, Australia
Ecklonia	***	Japan, China, Sth Africa
Egregia	*	Pacific Nth America
Eisenia	*	Japan
Fucus	**	W. Europe
Hedophyllum	*	N America
Himanthalia	*	Portugal
Hormophysa	*	India
Laminaria	***	W Europe, Sth Africa, China, Iceland, UK, Nth America
Lessonia	*	Colder Southern Atlantic & Antarctic Oceans
Macrocystis	***	California, Mexico, Falklad Is, China
Nereocystus	*	Alaska, USA
Pelvetia	*	Cold Pacific & Atlantic Coasts
Pocockiella	*	India
Postelsia	*	California
Sacchorhiza	*	Cold Atlantic
Sargassum	**	Korea, Japan, India
Turbinaria	*	Indonesia

Table 5. Alginate bearing seaweeds by genus and countries where used.

3 VALUE OF WORLD/ASIAN TRADE IN EDIBLE SEAWEEDS

Use of seaweeds as a food item is not restricted to Asian countries but occurs world wide. In Europe, Dulse (*Palmaria palmata)* and Laver (*Porphyra laciniata)* are two seaweeds that are consumed. Dulse, a red seaweed, is eaten on its own or separately with dried fish, butter and potatoes. Laver, a leafy red seaweed, is eaten in soups and stews or is deep fried in fat with oats (laverbread). Also, Irish Moss (*Chondrus crispus)* another red algae, is boiled and mixed with milk to form a gel and is the origin of the well known 'blancmange'. Other countries that have a history of seaweed use are the Hawaiian Islands, South America, New Zealand, South Africa, USSR and Iceland. By far the greatest users of seaweeds for edible purposes however are in the Asian countries, principally Japan, Korea, China, Indonesia, and the Philippines, as a result this report focuses on this area.

3.1 Value of world trade in 1980.

The International Trade Centre estimated world trade in seaweed colloids in 1980 to be US$297 million*. This was proportioned as follows:- Agar (excluding China) US$117 million, Alginate US$125 million and Carrageenans US$55 million. Exact figures for the value of world trade in edible seaweeds are not available but it is reported that an estimated 475 000 tonnes of edible seaweeds were traded in Asia in 1980 (Mc Hugh and Lanier 1983). The 1982 export prices of Korean edible seaweeds was high compared with other types; red lavers between US$8 000-$10 000 per tonne, green lavers and kelp tangles US$6 000 per tonne. *Undaria*, the lowest priced of the edible seaweeds, fetched about US$1 300 per tonne (Mc Hugh and Lanier 1983). Present total value of trade is over a billion dollars.

*Appendix 2 contains US$-Aus$-Yen (¥) exchange rates 1982-1988

3.2 Value of the Japanese trade in edible seaweeds since 1980.

Principal seaweed products consumed in Japan can be split into nori varieties, kombu and wakame. Tables 6-10 show Japanese trade in these products for the years 1980-84 (Nisizawa 1987). Table 11 shows the total of seaweeds imported by Japan for the period 1985-6 (JETRO 1987).

	1980	1981	1982	1983	1984
Harvest (tonnes)	1235	824	995	1094	1099
Value (000,000 ¥)	2110	1710	4982	4237	2625

Table 6. Annual production of dried aonori in Japan (1980-1984) *(Monostroma & Enteromorpha)*

	1980	1981	1982	1983	1984
Harvest (10,000,000 Sheets)	78	767	723	1042	867
Value (1,000,000,000 ¥)	111	97	127	127	112

Table 7. Annual production of hoshi nori *(Porphyra sp)* in Japan (1980-1984).

Year	Marine Fishery	Aquaculture	TOTAL
1975	157760	15696	173456
1980	124816	38562	163378
1983	129043	44345	173388

Table 8. Annual yields of Kombu (*Laminaria sp.)* in Japan (Tonnes Wet Weight)

Year	Culture	Yield (1000 tonnes) Wild	Total
1980	114	16	130
1981	91	14	105
1982	118	12	130
1983	113	10	123
		Value (1,000,000,000 ¥)	
1980	13.9	2.6	16.5
1981	9.8	2.6	12.4
1982	14.9	1.9	16.8
1983	13.9	1.7	15.6

Table 9. Yield of wakame *(Undaria sp.)* in Japan on a wet weight basis (1980-1983)

Year	Amounts (tonnes)		Cost (1000 US$)	
	Korea	China	Korea	China
1981	26962	16	34728	16
1982	23357	513	29789	440
1983	24032	951	30472	840

Table 10. Amounts (wet weight) and cost of wakame products imported by Japan (1981-1983).

Country and Species	1985 Quantity	Value	1986 Quantity	Value
Hijikia fusiformis				
R Korea	2762703	2957169	2774790	2951221
China	44545	11171	44740	8195
Undaria fusiformis				
R Korea	26691576	9495406	25864007	7001548
China	2515450	613780	2893800	510087
Other edible seaweeds				
R Korea	652963	232230	1027860	246296
N Korea	–	-	2080	475
China	506220	181053	571210	194008
Taiwan	40865	35067	16745	10467
Phillipines	23144	7151	43232	11809
Norway	6000	1345	272500	3151
U.K.	–	–	4570	1305
FR Germany	86	372	–	–
U.S.A.	248	227	–	–
France	–	–	1012	496
TOTAL	**33243800**	**13534971**	**33271296**	**10939058**

Table 11. Amounts (kg) and cost (1 000 ¥) of seaweeds imported by Japan (1985-1986)

3.3 Trends in Japanese Trade 1985/86.

In 1986, seaweeds exported by Japan had a value of AUS$23.31 million. In the same year, Japan imported nearly three times this value (AUS$63.51). Export volume of nori related seaweeds was 195.83 million sheets, down 4.7% from the previous year. 2,615 tonnes of kelp was exported, down 5.7% from the previous year. 281 tonnes of toasted and seasoned seaweeds were exported, up 9.8% on the previous year. Dried seaweeds and kelp were exported to Taiwan. Toasted and seasoned seaweeds were exported mainly to the U.S.A. and Hong Kong.

The export price of nori-related products was $42.86 per 1000 sheets, up 16.2% on the previous year. The export price of kelp was $4 734 per tonne, up 46.4% on the previous year. The price of kelp recovered to a level of 1985 (figures from JETRO, 1987).

3.4 Japanese Demand and Supply Trends.

Recent technological advances in cultivating *Porphyra* has led to supply exceeding demand 10.4 billion sheets of dried seaweeds were produced domestically in 1986. Dried nori is not imported.

Although there is a steady demand for kelp as a health food, the supply has increased in recent years, and prices have been hanging low. 130 000 tonnes of natural kelp and 54 000 tonnes of cultured kelp was produced domestically in 1986. The total domestic production of kelp was 184 000 tonnes down 1.3% on 1985 (JETRO 1987).

Production of wakame also exceeds demand and organizations are adjusting production following the introduction of artificial cultivation methods on rafts and ropes in the 1960's (Hay and Luckens 1987). As domestic prices of wakame are stabilized, the stock of wakame is adjusted under the governments instruction. Japanese and Korean commercial organizations have reached an agreement to export 24500 tonnes of salted Korean wakame to Japan in 1987, by June 1987 however this had already been exceeded. In China, it is believed that more wakame rather than kelp is being produced, this may also be destined for the Japanese market.

The demand for edible seaweeds in general, is steady due to health and natural food booms, steady demand is expected in the future.

3.5 Japanese Seaweed Prices

Table 12 (taken from Nisizawa 1987) gives an indication of the prices received at various levels for the major seaweed products eaten in Japan.

Product	Price per kg. (AUS$)
Purple laver (nori) *(Porphyra sp.)*	
Local Fisheries Coop Association (LFCA)	38.23
Retail	83.33-100.00
Green laver (Ao nori) *(Monostroma/ Entromorpha)*	
LFCA	16.00
Kombu *(Laminaria sp)*	
LFCA	12.00- 16.00
Hiziki *(Hizikia fusiformis)*	
LFCA	12.00- 13.00
Retail	30.00
Wakame *(Undaria sp)*	
Import price	1.80
Retail	18.00- 30.00

Table 12. Price per kilogram (AUS$) for popular seaweed products. (1985) (from Nisizawa 1987)

The retail price of wakame given above contrasts with the cost of *Undaria* available in Australia available through local Health Food Shops. Spiral Foods (Richmond, Vic.) import *Undaria pinnatifida* or wakame from Japan in bulk. This is packaged and can be purchased at a retail price of $4.10 for 50gms at 'Eumarrah Health Foods', Sandy Bay, Tasmania. This is equivalent to $82.00 per kilo, dry weight (*Undaria pinnatifida* has recently been found growing on Tasmania's east coast and could be harvested and marketed internally at competitive prices, provided an acceptable product was produced).

3.6 General conditions of trade in Asia and the U.S.A.

The production of Wakame in Korea reached 354 661 tonnes in 1986, an increase of 34.9% on 1985. Almost all of this was cultured (346 434 tonnes cultured, 8 227 tonnes wild). Production of Hijiki (seaweed product using a species of brown seaweed) in Korea also increased to 24 919 tonnes (13 289 tonnes cultured, 11 630 tonnes wild), an increase of 4.1% from the previous year. Korea allocates export quotas to processing factories and trading companies for export to Japan under the instruction of the Japanese Fisheries Agency. Korea also introduces a price checking system for export prices. Products whose prices are above a certain level can be exported under this price checking system.

All edible seaweeds imported by Taiwan came from Japan. The import volume in 1986 was 2 764 tonnes, down 7.4% on the previous year. The import value however, increased to $419.03 million, (16.7% increase) reflecting the appreciation of the Yen.

The U.S. seaweed market is classified into those for toasted seaweeds for Japanese restaurants and dried, toasted and seasoned seaweeds for retail shops. Markets for restaurants account for 70% while those for retail shops account for 30%. The U.S market is shared by Japanese, Korean and other seaweeds on a ratio of 2:2:1. Korea managed to greatly increase its share of the market while Japan faced sluggish exports due to the Yen's appreciation. The Korean share has doubled in the past five years.

In China, kelp is produced mainly by culture in the coastal areas. Some areas previously involved in the culture of Kelp for the Japanese market have been reported to be shifting production to wakame.

3.6 Prospects for the Japanese trade.

From these figures, it would appear that Japan is supplementing internal wakame, hizikia and kelp production from Korea with possibly more coming from China in the future. Domestic production of nori related seaweeds within Japan, continues to be in excess however and none will be imported in 1988. Other types of seaweeds are supplied from outside Japan to the value of Aus$3 million dollars in 1986 (see Table 12) but a breakdown of these figures does not enable us to determine which varieties. It is probably in this area that Tasmania has the best chance of breaking into, the supply of the more exotic weeds. It is expected that demand for edible seaweeds within Japan will remain steady in the future, basically due to health and natural food booms.

4 AUSTRALIAN SEAWEED TRADE

4.1 Australian Consumption of Seaweeds.

It is difficult to determine precisely the quantities and values of seaweeds that are imported by Australia. Historically, the Australian Bureau of Statistics has included seaweed imports within a broad category entitled 'other vegetable products'. Seaweeds will however, be specifically identified when a new collation procedure is adopted in 1989. At present, seaweeds are imported from several Asian countries, and a survey of several Australian Health Food shops indicates that most imports are from Japan. Japanese statistics on quantities exported to Australia for 1984-1986 are provided in Table 13.

Although there are insufficient records to suggest any trend, it seems likely that demand will increase given the growing influence and popularity of Asian-style food in Australia.

	1984	1985	1986
Edible dry lavers in rectangular sheets	3310	2694	2023
Other dried tangules	510	3031	
Edible Seaweeds (N.E.S.)	2924	15204	6117
TOTAL	6744	20929	8140

Table 13. Value of edible seaweeds imported into Australia from Japan. (¥1 000). (From JETRO 1987)

The extent that local seaweed species may be used for the Australian domestic market depends on price, quality and especially substituteability. The main competitive edge that a local product would have relates to the strength of the Yen against the Australian dollar.

4.2 Existing industry.

Kelp Industries, a King Island based firm, has been involved with the export of dried and crushed bull kelp (*Durvillaea potatorum*) for the past fifteen years. Storm cast plants are collected using four wheel drive vehicles and trailers or heavy rigid trucks. The kelp is dragged onto the trailers and transported to the Kelp Industries factory where it is lifted mechanically onto drying racks. It is the responsibility of the harvester to ensure that the kelp is dried, milled and packed before he receives payment based on the dried weight. Once the kelp is packaged it is transported by container to the parent company of in Scotland where it is processed to extract Alginate. Personal communication with Mr Frank Cullen of Kelp Industries revealed an expectation to process approximately 3 700 tonnes (dry weight) of Bull Kelp in 1988. The value of this to harvesters will be around $2 million. Harvesters receive 57c per kilogram .

Cullen estimates that between 4000 to 6000 tonnes of Bull Kelp are cast up on King Islands beaches each year. Quantities of kelp harvested has increased over the past four years; (2 013, 2 100 and 2 578 tonnes in 1985, 1986 and 1987 respectively). The largest harvest over a twelve month period has been 3 200 tonnes.

As the quantities processed by Kelp Industries is dictated by the needs of the partner company in Scotland, quantities harvested up till now have been within the limits of the available resource. However it is predicted this year that their may not be enough storm cast kelp to satisfy the demand.

Kelp Industries is also involved in a two year trial to explore the possibilities of exporting dried storm cast *Gelidium* sp. (principally *Gelidium gladulaefolium)* to Japan for agar extraction. Funding from Federal and State government enabled Kelp Industries to send a one tonne trial shipment to Japan in 1987. This is to be followed by a container (seven tonnes) in the near future. At present harvesters receive $1.50 per kilogram (dried weight). The price received by harvesters is dependant on the price Kelp Industries receive for the dried product in Japan. Mr Cullen predicts that the price to harvesters could soon increase to $2.00 per kilogram. Should it prove feasible to export *Gelidium sp.* in the long term, Kelp Industries will produce a management plan outlining the future of the industry.

5 POTENTIALLY USEFUL TASMANIAN SEAWEEDS.

5.1 Potential Edible Tasmanian Seaweeds.

Table 14 lists Tasmanian species of equivalent genera to those utilized elsewhere (see Table 2), their distribution, habitat and an indication of relative abundance (species list obtained from Sanderson, 1988). Being of the same genera however, does not automatically indicate that they are good substitutes for species used elsewhere, for example, in the case of edible seaweeds, an attempt has been made to distinguish two similar species of *Ecklonia* in Japan by their taste. *Ecklonia cava* contains bitter salts of potassium, sodium, and carbonic soda while *Ecklonia kurome* produces mannitol, a white powder like substance which appears on the surface of the frond when it is dried, producing a good, sweet taste (Madlener 1977). When wet, both species taste similar but when dry have opposite flavours due to differing concentrations of component compounds. It is not uncommon however for more than one species of a genus to have similar qualities as evidenced by *Porphyra*. In Japan *P. yezoensis* and *P. tenera.* are used extensively for nori production while outside of Japan, other species of *Porphyra* are utilized such as *P. crispata, P. dentata, P. nereocystis, P. perforata, P. pseudolinearis, P. suborbiculata and P. umbilicalis*. The real test of the Tasmanian species suitability for overseas markets comes from utilization on a trial basis.

Genera	Species	Distribution	Intertidal/ subtidal	Exposure to wave action	Relative quantities available
			CHLOROPHYTA		
Caulerpa	*annulata*	T	S	M	*
	brownii	T	I-S	M	***
	cactoides	NT	S	L-M	*
	flexilis	T	I-S	M-H	***
	geminata	T	I-S	L-M	***
	longifolia	T	I-S	L-M	**
	obscura	NT	I-S	L-M	**
	scalpelliformis	T	I-S	L-M	*
	simpliciuscula	T	I-S	L-H	***
	trifaria	T	S	L-M	**
	vesiculifera	NT	I-S	M	*
Chaetomorpha	*aerea*	T	I-S	M	*
	billardieri	T	S	S-M	**
	coliformis	T	I-S	M	**
	valida	T	S	S-M	*
Codium	*australicum*	T	S	M	*
	dimorphum	T	S	M	*
	duthicae	T	S	M	**
	fragile	T	I-S	M	**
	galeatum	NT	S	M	*
	harveyi	T	S	M	*
	perriniae	T	S	M	*
	pomoides	T	S	M	**
	spongiosum	T	S	M	*
Enteromorpha	***clathrata***	T	I-S	S-M	**
	intestinalis	T	I-S	S-M	**
	prolifera	T	I-S	S-M	**
Ulva	*australis*	T	I-S	S-M	**
	lactuca	T	I-S	S-M	***
	rigida	T	I-S	S-M	*
	taeniata	T	I-S	S-M	**
			PHAEOPHYTA		
Chordaria	*cladosiphon*	T	I-S	S-M	**
Dictyopteris	*muelleri*	T	I-S	S-M	**
Ecklonia	*radiata*	T	I-S	S-H	***
Hydroclathrus	*clathratus*	NT	I	S-M	*
Macrocystis	*angustifolia*	NT ?	I-S	M	***
	pyrifera	T	S	M	***
Padina	*fraseri*	NT	I-S	S-M	*
Petalonia	*fascia*	T	I-S	S-M	*
Sargassum	*decipiens*	T	I-S	S-M	**
	fallax	NT	I-S	S-M	**
	heteromorphum	NT	I-S	S-M	***
	paradoxum	T	I-S	S-M	***
	sonderi	T	I-S	S-M	**
	varians	NT	I-S	S-M	**
	verruculosum	T	I-S	S-M	***
	vestitum	T	I-S	S-M	**
Scytosiphon	*lomentaria*	T	I-S	S-M	**
Tinocladia	*australis*	T	I-S	S-M	*
			RHODOPHYTA		
Asparagopsis	*armata*	T	I-S	S	**
Bangia	*atropupurea*†	T	I-S	S-M	*
	fuscopurpurea	T	I-S	S-M	*

continued.

Genera	Species	Distribution	Intertidal/ subtidal	Exposure to wave action	Relative quantities available
Bostrychia	*harveyi*	T	I-S	S-M	*
	mixta	T	I-S	S-M	*
	simpliciuscula	T	I-S	S-M	*
Caloglossa	*leprieurii*	T	I-S	S-M	*
Carpopeltis	*phyllophora*	T	I-S	M-H	*
Catenella	*opuntia*†	T	I-S	S-M	*
Gelidium	*australe*	T	I-S	M-H	**
	glandulaefolium	T	I-S	M-H	**
	pusillum	T	I-S	M-H	*
Gigartina	*conferta*	NT ?	I-S	S-M	*
	corniculata	NT ?	I-S	S-M	*
	pinnata	T	I-S	S-M	*
	radula	T	I-S	S-M	**
	recurva	T	I-S	S-M	**
	revoluta	T	I-S	S-M	**
	rubra	T	I-S	S-M	**
Gliosaccion	*brownii*	T	I-S	S-M	**
Gracilaria	***confervoides***	T	I-S	S-M	**
	lichenoides†	T	I-S	S-M	**
Grateloupia	***filicina***	T	I-S	S-M	**
	intestinalis	T	I-S	S-M	**
	prolifera†	T	I-S	S-M	*
Gymnogongrus	*fastigiatus*	T	I-S	M	*
Hypnea	*episcopalis*	T	I-S	S-M	**
Iridaea	*polycarpa*†	T	I-S	M	*
Laurencia	*botryoides*	T	I-S	M	**
	elata	T	I-S	M	**
	filiformis	T	I-S	M	**
	majuscula	T	I-S	M	**
	tasmanica	T	I-S	M	**
	tumida	T	I-S	M	*
Liagora	*harveyana*	NT	I-S	S-M	*
Nemalion	*helminthoides*	T	I-S	S-M	*
	multifidum	T	I-S	S-M	*
Porphyra	*columbina*	T	I-S	S-M	**
	laciniata†	T	I-S	S-M	**
	umbilicalis†	T	I-S	S-M	**
Prasiola	*crispa*	ST?	I-S	S-M	*
Rhodymenia	*australis*	T	S	M	**
	cuneata	T	S	M	*
	foliifera	T	S	M	*
	linearis	NT?	S	M	*
	pinnulata	NT?	S	M	*
Sarcodia		T	I-S	S-M	*
Scinaia	*forcellato*	T	I-S	S-M	*

Table 14. Comparable genera of Tasmanian seaweeds to those utilized elsewhere
A. Species names in bold are Tasmanian species that are the same as those used elsewhere. Those marked with an †, are uncertain species identifications.
B. Distribution - [T = circum Tasmania; ST = confined to Southern Tasmania; NT = confined to Northern Tasmania]
C. Intertidal/Subtidal - [S = Subtidal; I = Intertidal, including rockpools]
D. Exposure - [S = Sheltered; M = Moderate; H = High]

5.2 Potential Agar Producing Tasmanian Seaweeds

Table 15 shows equivalent Tasmanian genera to those utilized elsewhere for the production of agar (see Table 3), their distribution, habitat and an indication of relative abundance.

Genera	Species	Distribution	Intertidal/ subtidal	Exposure to wave action	Relative quantities available
Brongniartella	*australis*	NT	I-S	S-M	*
Ceramium	*fastigiatum*†	T	I-S	S-M	**
	flaccidum	T	I-S	S-M	**
	monacanthum	T	I-S	S-M	**
Gelidium	*australe*	T	I-S	M-H	**
	glandulaefolium	T	I-S	M-H	**
	pusillum	T	I-S	M-H	**
Gracilaria	***confervoides***	T	I-S	S-M	**
	lichenoides†	T	I-S	S-M	**
Grateloupia	***filicina***	T	I-S	S-M	**
	intestinalis	T	I-S	S-M	**
	prolifera	T	I-S	S-M	*
Gymnogongrus	*fastigiatus*	T	I-S	S-M	*
Peyssonnelia	***capensis***	T	S	S-H	***
Pterocladia	***capillacea***	T	I-S	M-H	**
	lucida†	T	I-S	M-H	**
	glandulaefolium	T	I-S	M-H	**

Table 15. Comparable genera of Tasmanian seaweeds to those utilized elsewhere for agar production

A. Species names in bold are Tasmanian species that are the same as those used elsewhere. Those marked with an †, are uncertain species identifications.

B. Distribution - [T = circum Tasmania; ST = confined to Southern Tasmania; NT = confined to Northern Tasmania]

C. Intertidal/Subtidal - [S = Subtidal; I = Intertidal, including rockpools]

D. Exposure - [S = Sheltered; M = Moderate; H = High]

5.3 Potential Carrageenan Producing Tasmanian Seaweeds.

Table 16 shows equivalent Tasmanian genera to those utilized elsewhere for the production of carrageenan (see Table 4), their distribution, habitat and an indication of relative abundance.

Genera	Species	Distribution	Intertidal/ subtidal	Exposure to wave action	Relative quantities available
Aeodes	*ulvoidea*	T	S	S-M	*
Delisea	*australasica*	T	I-S	S-M	*
	elegans	T	I-S	S-M	**
	hypneoides	T	I-S	S-M	**
	pulchra	T	I-S	S-M	**
Gigartina	*conferta*	NT ?	I-S	S-M	*
	corniculata	NT?	I-S	S-M	*
	crassicaulis	T	I-S	S-M	**
	pinnata	T	I-S	S-M	*
	radula	T	I-S	S-M	**
	recurva	T	I-S	S-M	**
	revoluta	T	I-S	S-M	**
	rubra	T	I-S	S-M	**
Gliosaccion	*brownii*	T	I-S	S-M	**
Hypnea	*episcopalis*	T	I-S	S-M	**
	seticulosa†	T	I-S	S-M	*
Iridaea	*polycarpa*†	T	I-S	S-M	*
Pachymenia	*apoda*	T	I-S	S-M	*
	lusoria	T	I-S	S-M	*
	orbicularis†	T	I-S	S-M	*
	stipitata†	T	I-S	S-M	*
Rhodoglossum	*polycarpum*†	T	I-S	S-M	*
	purpureum†	T	I-S	S-M	*

Table 16. Comparable genera of Tasmanian seaweeds to those utilized elsewhere
A. Species names in bold are Tasmanian species that are the same as those used elsewhere. Those marked with an †, are uncertain species identifications.
B. Distribution - [T = circum Tasmania; ST = confined to Southern Tasmania; NT = confined to Northern Tasmania]
C. Intertidal/Subtidal - [S = Subtidal; I = Intertidal, including rockpools]
D. Exposure - [S = Sheltered; M = Moderate; H = High]

5.4 Potential Alginate Producing Tasmanian Seaweeds

Table 17 shows equivalent Tasmanian genera to those utilized elsewhere for the production of alginate (see Table 4), their distribution, habitat and an indication of relative abundance.

Genera	Species	Distribution	Intertidal/ subtidal	Exposure to wave action	Relative quantities available
Durvillaea	*potatorum*	ST	I-S	M-H	***
Ecklonia	*radiata*	T	I-S	S-H	***
Hormosira	*banksii*	T	I	S-M	**
Lessonia	*corrugata*	T	I-S	M-H	**
Macrocystis	*angustifolia*	NT ?	I-S	M	**
	pyrifera	ST	S	M	***

Table 17. Comparable genera of Tasmanian seaweeds to those utilized elsewhere
A. Species names in bold are Tasmanian species that are the same as those used elsewhere.
B. Distribution - [T = circum Tasmania; ST = confined to Southern Tasmania; NT = confined to Northern Tasmania]
C. Intertidal/Subtidal - [S = Subtidal; I = Intertidal, including rockpools]
D. Exposure - [S = Sheltered; M = Moderate; H = High]

6 MARKET SURVEY

6.1 Aim

For Japanese companies to develop a commercial interest in Tasmanian seaweed resources.

6.2 Method

Initial contacts were made with approximately 80 Japanese trading companies involved in the fisheries industry to determine if they were interested in Tasmanian seaweeds and to ask advice about preparation techniques, harvesting details and what types of edible seaweeds were required.

This was followed by a sample package being distributed to a number of people and companies known to be involved in the edible seaweed industry. Contents of the sample packages varied. All received the following species which were abundant on Tasmanian shores:-

Macrocystis pyrifera.
Durvillaea potatorum
Caulerpa brownii
Codium sp.
Ecklonia radiata.

The seaweed samples were air dried at 50°C in a drying cabinet at the Mechanical Engineering Department at the University of Tasmania and then vacuum packed at CSIRO Food Laboratories, Stowell Ave., Hobart.

Twelve of the sample packages contained a small amount of *Undaria pinnatifida* found growing on the east coast of Tasmania. A sample sent to Professor Arasaki (considered to be one of the foremost authorities on edible seaweeds in Japan) also contained samples of the following weeds; *Caulerpa racemosa, Caulerpa annulata, Sargassum* sp., *Gracilaria* sp., *Cystophora torulosa. Chaetomorpha coliformis, Gigartina* sp., *Grateloupia filiciana* and *Dictyopteris muelleri.*

In total twenty sample packages were distributed. The majority went to trading companies, and included a letter expressing our desire to receive notification of any commercial value that they might have. The letter made clear that the samples were not prepared in any special way and if the company believed the sample might have commercial value, we could arrange to have the seaweeds presented in a way that would make them more attractive. It also mentioned that we are ignorant as to the optimum time to harvest seaweeds, so the sample weeds may have been less than top quality.

A sample was also sent to Ken Suzuki of Austrade.

6.3 Results

A positive response for edible seaweeds was received from-

Yokohama Pty Ltd.. This company requested by telex:

Ecklonia & *Durvillaea* for alginates.
Gigartina & *Grateloupia* for the edible market and
Gracilaria & *Gelidium* for agar

Other less positive responses were received from-

Ken Suzuki. In addition to the five seaweeds listed above, the package sent to Mr Suzuki contained *Grateloupia filicina, Dictyopteris muelleri* and *Chaetomorpha coliformis* . On our behalf Mr Suzuki approached the Nishisai Shoten Co. Ltd., one of the major seaweed wholesalers in Tokyo and requested an estimation of the commercial value and marketability of the samples in Japan. From texture, taste and other characteristics of the eight seaweeds it was decided that they had little or no value as edible seaweeds. A company called Ina Food Industry Co. Ltd. presented the samples to 'many customers'. They also were rejected them as being 'too large and bad in colour'.

Other responses came from-

Shinkyo Ind. Inc. This company requested (also by telex) *Hormosira banksii* for feed and fertilizer.

Manhattan Enterprises was interested in obtaining a seaweed similar to Kombu, from which they extracted a substance used in a 'bath product'.

In addition to the companies that received samples of Tasmanian seaweeds, Mr Frank Cullen of Kelp Industries supplied addresses of Japanese Companies that had contacted him to request seaweeds for the edible market. These were Tasman Goshu Trading Co., Nomura Pty. Ltd., Nippon Shoji Kaisha Ltd. and Manhatten Enterprises Pty. Ltd. Time did not allow for these companies to be followed up.

Finally, Mr Jiri Wein and Etsuko Seki, who were researching Tasmanian seaweeds for a book on edible seaweeds of the world, and who visited Tasmania in 1987, are interested in revisiting the state to examine its seaweeds in greater detail. For in their opinion (pers comm. 13 April 1988) the Tasmanian seaweed flora has great potential.

6.4 Conclusions

Only a limited response was obtained to our requests, this may have been due to the following factors:

1 the list of companies that received our letter were 'marine importers', very few of which may actually deal in seaweed.

2 there is a possibility of degradation of the seaweed samples due to inexperience on our part in packaging techniques.

3 review of the literature indicates the optimum time to harvest seaweeds for Kombu in Japan as the period from the end of May to September (Nisizawa 1987) and many authors allude to optimum harvesting times for best product. Our harvesting time (February) may not have been during the optimum period.

4 *ignorance as to how to present the seaweeds in a manner likely to appeal to the Japanese.*

From our efforts to establish an interest in edible species of Tasmanian seaweed we consider that a 'hands on' knowledge of the present edible seaweed market to be invaluable. For example, the presence of somebody with the expertise of Jiri Wein and Etsuko Seki would greatly assist any further attempts to initiate an industry here in Tasmania.

7 ESTIMATED COST OF PRODUCTION

For some species of seaweed, it may be necessary to investigate methods of mariculture for example if it was considered that harvesting may be deleterious to the environment or if there was not sufficient quantities of the seaweed available. Different species require different methods of culture. Three systems and their estimated costs are presented here.

1 Enclosed pond, suitable for eg.*Gracilaria* and *Gelidium* mariculture.

2 Suspended nets, suitable for eg. nori or *Porphyra* culture.

3 Longline cultivation, suitable for many species of brown algae.

Seeding of Ropes/Nets

Technology for seeding ropes and nets by algal spores is not yet established in Tasmania, but the method is well known. For the following cost estimates, assume that seeding is done in available hatcheries, for the cost of two men for two days.

7.1 Enclosed pond.

This estimate is for the manufacture and running costs of four ponds 8 m. in circumference, 0.5 m. deep and fed from the sea. It is assumed that land space is available and that one person can run the site.

Capital Costs

Item	Type	Length (m.)/No.	Cost/ Unit $	Total Cost $	Life time (Yrs)	Cost/ Yr $
Ponds, F/glass	8 m. diam. x 0.5 m.	4	3000	12000	10+	1200.00
Header Tank Concrete	15,000 litre	1	5000	5000	10+	500.00
Pump	'Onga' 320 l./min.	2	400	800	1	800.00
Pipe	PVC,5 cm	100	3.11	311	5	62.20
Aeration Facilities						1000.00
Establishment Costs	2 x men x 5 days		90	900	5	180.00
Other						
Fertilizer						1000.00
Power						2000.00
Total capital						**6742.20**

Labour

Nature of Work	No. of Men	No. of Days	Cost/man /day $	Total Cost $
Establishment	2	5	90	900
Maintenance/harvest-1/f'night/yr	1	26	90	2340
Total labour				**3240**
TOTAL				**9982.20**

Gracilaria - typical rates are 5-10%/day for initial stocking densities of approximately 3 kg/m^2.

Gelidium - 2.5%/day for initial stocking densities of 2.5-3.2 kg/m^2 (Hansen et al. 1981).

Gracilaria

Assume 7% day and a total area of 200 m^2

200 m^2 x .21 kg/m^2/day x 365 = 15,330 kg wet wt = 3,000 kg dry wt

Approximate cost to produce - $3,300/tonne.dry wt.

Price of alga in Japan (for agar): *Gracilaria* $3046/tonne (Armisan & Galatas 1987)

Gelidium

Assume 2%/day for initial stocking densities of 3 kg/m^2

200 m^2 x .06 kg/m^2/day x 365 = 4380 kg wet wt = 876 kg dry wt

Approx. cost to produce - $11,400/tonne dry wt.

Price of alga in Japan (for agar): *Gelidium* $3743-/tonne (1984) (Armisan & Galatas 1987)

Note: All Australian price estimates using current ¥:Aus$ conversion of 100:1.

Means of cost cutting:

Expenditure may be reduced by:

(a). Culturing other species (eg abalone) simultaneously,

(b). Shifting from intensive pond culture to enclosures in the sea. Although algal productivity in the open sea is likely to be less than that attained in pond culture, it is possible that any disparity is minimized by siting the enclosure close to salmon farms where concentrations of nutrients are relatively high.

7.2 Suspended nets.

Methods for culturing species of *Porphyra*, follow those of the Japanese, who for the majority of cultured *Porphyra* suspend nets within the intertidal region, growing in deeper waters is also a possibility. For this example I assume a manageable farm to be 400 meters x 2 meters.

Costs involved in establishment and maintenance:

Item	Type	Length (m.)/No.	Cost/ Unit $	Total Cost $	Life time (Yrs)	Cost/ Yr $
Shark Net	10 cm 'bar'	400	0.70	280.00	2	140.00
Pickets	Star	172	3.45	593.40	5	118.68
Total capital						**258.69**

Labour

Nature of Work	No. of Men	No. of Days	Cost/man /day $	Total Cost $
Seeding Nets	2	2	90	360
Deploying	2	2	90	360
Maintenance 1 day/fortnight/3 months	1	6	90	540
Retrieval/Processing	2	5	90	900
Total labour				**2160**
TOTAL				**2418.69**

Yields:

'A single net yields between 35 and 105 kg of wet *Porphyra* or 1000-3000 dried sheets of nori (Chapman and Chapman 1980) Assuming an average yield of 60 kg wet, or 3.3 kg dried nori per square metre, then the crop produced by an 800 m^2 farm would be 2640 kg wet or 528 kg dry.

Approx. cost to produce - $4.60/kg

Price of alga in Japan (1985) - $38-/kg (dry) wholesale, $80-100-/kg retail (Nisizawa 1987)

Means of Cost Cutting:

- grow in conjunction with other marine organisms eg oysters.

7.3 Longline Cultivation.

There are many options for designing longlines. Here we have budgeted for double 120 m. longlines with 40 m. cross lines every 20 m. thus giving a total rope length of 520 m available for cultivation of algae.

Capital Items.

Item	Type	Length (m.)/No.	Cost/ Unit $	Total Cost $	Life time (Yrs)	Cost/ Yr $
Rope	24 mm pp	720	1.81	1303.20	5	260.64
Anchor Weights	Bogey Wheels	8	27.50	220.00	5	44.00
Bouys	25 cm. 'AO'	33	14.00	462.00	5	92.40
Other						
Boat Charter (Deployment & Retrieval) 2 days @ $1200/day						2400.00
Total capital						**2797.04**

Labour

Nature of Work	No. of Men	No. of Days	Cost/man /day $	Total Cost $
Seeding Ropes	2	2	90	360
Deployment	2	1	90	180
Maintenance 1 day/month/6 months	1	6	90	540
Retrieval/Processing	2	5	90	900
Total labour				**1980**
TOTAL				**4777.04**

Yields:

Yields depend very much on the alga being cultivated. *Laminaria spp.* may yield anything from 3-24 kg/m. while *Alaria esculenta* ; 7.2 - 11.9 kg/m. and *Undaria pinnatifida* ; < 5 - 10 kg/m. (all wet weight) (Druehl 1987).

Assume yields of 8 kg/m./yr. giving for the growing season:

520 m x 8 kg/m. = 4160 kg wet wt or 594 kg dry wt.

Approx. cost to produce: $8.00/ kg dry wt.

Price of alga in Japan (edible purposes,1985):

Laminaria (Kombu)	$12-16-/kg dry, wholesale
	$30- retail
Undaria (Wakame)	$1.80- (?!) import price
	$18-30-/kg retail(Nisizawa 1987)

For alginate production (1987):

Durvillaea	$400/tonne
Laminaria	$500-700-
Ecklonia	$250- (Mc Hugh 1987).

Means of cost cutting:

-grow in conjunction with other marine organisms eg. scallops, mussels.

7.4 Conclusions

By far the most economically viable alga considered here is *Porphyra*, unfortunately there is little demand externally as all is supplied by the Japanese, the internal market may be a consideration however but here the the locally available species of *Porphyra* may not be suitable. Culture of other genera suitable for nori (eg. *Ulva*) products remains a possibility.

Longline and enclosed culture for the edible market are borderline economically, faster growing algae in enclosed culture system may prove profitable.

Growing algae for alginates or agar is not presently feasible but this may change for agar with the rise in the value of the Yen.

8 ARSENIC IN TASMANIAN SEAWEEDS

8.1 Introduction

High levels of arsenic would preclude any Tasmanian seaweed as an edible species with export potential. Toxicity of arsenic is thought to be dependant on its valence, whether it is in inorganic or organic form and the solubility of these compounds, it is more toxic in an inorganic form than an organic one, and in a reduced (valence usually +3) than in an oxidized form (valence usually +5) (Nisizawa 1987). Health Standard Regulations in Great Britain and North America specify an upper limit of inorganic arsenic concentration for seaweeds and kelps, for this reason inorganic as well as total levels of arsenic are measured.

There has been little research on the arsenic content of Australian seaweeds. The studies of Edmonds and Franseconi (1981, 1987) concerned the different arsenic compounds in *Ecklonia radiata* on the West Australian coast and Maher and Clarke (1984) analysed a wide range of seaweeds but tested only for total arsenic content and inferences must be made about relative concentrations of inorganic/organic arsenic from other studies. More extensive studies have been conducted on Japanese macroalgae with respect to the levels of inorganic and organic arsenic content (Nisizawa 1987) and in European and North American locations (Whyte and Engler 1983, Sanders 1979).

Studies so far suggest phosphate and arsenate compete for uptake in algae, the degree of arsenate uptake depending on the relative availability of phosphate (Sanders 1979). Likely sources of arsenic in aquatic systems are arsenic-rich rocks or industrial wastes washed into rivers and seas (Zingaro 1983). Unlike Western Australia whose waters are largely phosphate limited and to a lesser extent the waters of South Australia, southern Tasmanian waters do not suffer from significant phosphate limitations with respect to macroalgal nutrient requirements (Sanderson 1987). With the lack of industrial waste systems for much of the Tasmanian coast, most of the macroalgae could be expected to be relatively arsenic free.

8.2 Method

Two sampling sites were chosen, Southport, (Burial Ground Point) 100km south of Hobart and Lucas Point, near Hobart. The site at Southport is known to be bathed in relatively clean waters from the sub-antarctic, whilst the Lucas Point site is subject to waters from the Derwent River which contains effluent from the Zinc works just north of Hobart.

Species of algae for analysis were chosen on the basis of:

1. representative of Chlorophyta, Phaeophyta and Rhodophyta.
2. species that are comparable to edible species used elsewhere or which are abundant
3. species present at both sites.

Species chosen were;

Chlorophyta: *Caulerpa* spp.and *Ulva australis.*
Phaeophyta: *Ecklonia radiata* and *Sargassum paradoxum*
Rhodophyta: *Polyopes constrictus* and *Plocamium dilatatum*

No *Caulerpa brownii* was found at Lucas Point so plants of *Caulerpa simpliciuscula* were used instead. *Polyopes costricta* from Lucas Point was overgrown with epiphytes and could not be used. *Pterocladia glandulaefolium* from Burial Ground Point was also included. Herbarium specimens of all plants used are lodged with the Tasmanian State Herbarium. Both sites were sampled on the 29 May 1988.

Sufficient sample were collected to obtain at least 5 g of sample after removing epiphytes washing in deionized water, drying at 55°C for 48 hours and grinding in an agate mortar and pestle. Analyses for total and inorganic arsenic followed closely the method of Whyte and Engler (1983).

Seasonal samples of *Ecklonia radiata* were obtained from George IIIrd Reef, approximately 5 km south of Southport (see Sanderson 1987). These were stored in a freezer at -20°C until required for analysis.

8.3 Results

BURIAL GROUND POINT	TOTAL	INORGANIC	LUCAS POINT	TOTAL	INORGANIC
Caulerpa brownii	5.9	0.62	*Caulerpa simpliciuscula*	5.7	1.30
Ulva lactuca	5.7	0.32	*Ulva lactuca*	3.6	0.80
Polyopes costrictus	5.1	0.48			
Plocamium dilatatum	2.1	0.90	*Plocamium dilatatum*	7.6	1.0
Pterocladia glandulaefolium	1.0	0.58			
Sargassum paradoxum	119	106 (?)	*Sargassum paradoxum*	70.8	24.7
Ecklonia radiata			*Ecklonia radiata*	40.1	1.02
14/11/85	20	0.25			
23/ 3/86	4.4	1.10			
23/ 5/86	3.2	0.75			
14/ 9/86	24.3	1.1			

Table 18. Total arsenic (μg/g dry weight).

STUDY	LOCATION	Overall Arsenic Concentrations (Average μg/g) CHLOROPHYTA Total	CHLOROPHYTA Inorg	PHAEOPHYTA Total	PHAEOPHYTA Inorg	RHODOPHYTA Total	RHODOPHYTA Inorg
Sanders (1979)	Nth America	1.54	0.72	10.3	2.3	1.43	0.61
Whyte & Engler (1983)	British Columbia			61.1	2.3		
Edmonds & Francesconi (1981)	West. Australia			3.9	0.74 (?)		
Maher & Clarke (1984)	Stenhouse Bay, South Australia	11.4		94.2		23.9	
	Aldinga Beach, South Australia	10.3		45.5		15.0	
This Study (excluding results for *S. paradoxum*).	Lucas Point, Tasmania.	4.65	1.05	40.1	1.02	7.6	1.0
	Burial Ground Point, Tasmania.	5.8	0.47	12.23	0.8	2.73	0.65

Table 19. Comparative arsenic contents (μg/g)

Seaweed	Total Arsenic	Inorg. As.
Aonori (*Enteromorpha sp.*)	0.4-0.9	-
Kombu (*Laminaria japonica*)	60.1	0.83
Wakame (*Undaria pinnatifida*)	68.0	1.30
Hiziki (*Hizikia fusiforme*)	62.3	53.54
Nori (*Porphyra tenera* or *P. yezoensis*)	13-30	-

Table 20. Arsenic content of some edible seaweeds. (μg/g of dry matter, Nisizawa 1987).

8.4 Conclusions

From Tables 18-20 it can be seen that the total arsenic content of Phaeophyta in general is elevated with respect to members of the Rhodophyta and Chlorophyta. Within the Phaeophyta, members of the Sargassaceae have considerably higher concentrations of total and inorganic arsenic. This has been demonstrated consistently (Sanders 1979) for this group.

Determination of arsenic; total and inorganic exhibited some variation in results, this was attributed largely to uneven distribution of arsenic throughout the plant material and resultant samples. Taking this into consideration none of the plants (aside from *Sargassum paradoxum*) significantly exceeded 1.0 µg/g inorganic arsenic *dry weight*.. They therefore comply with the standards set by the Food Additives and Contaminants Committee, Great Britain (1.0 µg/g inorganic arsenic) and the Food Chemicals Codex of the USA, 1981 (3.0 µg/g inorganic arsenic). Within Australia however, other than in the state of Victoria (1.0 µg/g inorganic arsenic, the same as for fish), limits are based on the *total* amount of arsenic, and in Tasmania this level is 1.0 µg/g. Only one of the plants tested, *Gelidium glandulaefolium* is within this standard. As it is known that the toxic form of arsenic makes up only a small percentage of the total found in these plants review of this legislation regarding allowable arsenic concentrations is due.

The seasonal variation of internal arsenic concentration for *Ecklonia radiata* demonstrates a possible connection with nutrient levels in the water but not sufficient to cause greatly elevated levels of inorganic arsenic within the plants. There is no reason to believe that plants harvested from coastal waters of southern Tasmania are likely to have significant quantities of inorganic arsenic and are thus safe for human consumption.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Edible Seaweeds

- Total world wide market in edible seaweeds is presently estimated at over 1 billion dollars.
- There is a large market for edible seaweeds in Asia, particularly Japan, met at present for the most part internally, and principally by mariculture. Japan, the largest consumer, imported seaweeds in addition to the most common seaweed products; nori, kombu and wakame to the value of Aus $3 million dollars in 1986.
- There have been several requests have been received for samples of *Grateloupia sp.*, *Gigartina sp.* and *Meristotheca papulosa* showing a demand for seaweed

products other than nori, kombu and wakame. These requests, where possible, need to be followed through.

- Tasmania has many seaweed species similar to varieties utilized elsewhere. Some of these are abundant.
- The Japanese market for edible seaweed is discerning and difficult to enter. Therefore it is essential to consult someone familiar with Asian tastes, preparatory techniques and the Asian market prior to the development of any Tasmanian product.
- The cost of mariculture of seaweeds for the edible market is a viable proposition in Tasmania particularly in a polyculture situation.
- Tasmanian seaweeds tested for arsenic were within levels specified as safe by British and American Health standards. Review of Australian National Health Regulations in regard to allowable levels of arsenic in edible seaweeds is due.
- Tasmanian waters are very clean with respect to pollutants than elsewhere. This should be considered as a marketing attribute.
- A tendency for the Australian dollar to devalue relative to the Yen makes harvesting of comparable seaweeds here in Tasmania for the Japanese market an increasingly financial proposition.

9.2 Agar

- Current research on utilizing southern Australian seaweeds for agar is being conducted at the University of Adelaide in to the use of southern Australian weeds for agar manufacture (Gordon-Mills 1987). Close contact should be maintained with this research unit to determine any possible areas for collaboration. There are many potential agar bearing weeds in Tasmania waters and the existence of an Australian based processor would increase the chances of the financial viability of developing this resource.
- In New Zealand, polyculture has developed with abalone and macroalgae (Redford pers comm). The cultured macroalgae has in turn been used for agar production. With the developing abalone culturing industry here in Tasmania, this aspect may also be considered here. Sale of agar bearing weed to New Zealand is also an option.
- The success of the King Island operation with respect to the collection of the beach cast Gelidium should also be monitored. The decreasing value of the Australian dollar against the Yen may make it worthwhile to collect algae in other areas for export overseas.

9.3 Alginates

- King Island continues to be a valuable source of Bull Kelp for Alginate Inds (a subsidiary of Meurk) and presently, demand is only just meeting supply (Cullen pers. comm.). The present moratorium on harvesting Bull Kelp may be in need of review for while it has been *claimed* that the adult plants are a nursery for juveniles and harvesting of the adults lays open future generations to be washed away by big seas, some form of harvesting strategy may circumvent this. Either a size limit on the plants or harvesting in strips or patches. This area requires more research.

9.4 Carrageenan

- The introduction of aquaculture to the Phillipines and other Asian countries has stabilized supply of seaweeds used for this purpose. It would be difficult to compete with these sources.

9.5 Other

- The beneficial use of *Durvillaea* as a fertilizer has been recognized and the Melbourne based (originally Launceston) Sea-Sol which uses *Durvillaea* for its liquid fertilizer is expanding. Use of dried *Durvillaea* as fertilizer on macadamia nut plantations is becoming popular in NSW and Queensland.

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APPENDIX 1 Species of macroalgae used world-wide.

Use: Al = Alginates, Ag = Agar, Fo = Food, Ca = Carrageenan, Fert. = Fertilizer, Med. = Medicinal, Fd = Fodder
Value: ranked from 1 (least) to three (most) stars.

Genus	Species	Use	Value	Where Used	Reference
			CHLOROPHYTA		
Caulerpa	clavifera	Fo	*	Hawaii	Chapman & Chapman (1980)
	laetevirens	Fo	*	Indonesia	Arasaki & Arasaki (1983)
	okamurai	Fo	**	Japan	Arasaki & Arasaki (1983)
	peltata	Fo	*	Indonesia	Arasaki & Arasaki (1983)
	racemosa	Fo	**	Indonesia, Japan Phillipines, Taiwan, China	Arasaki & Arasaki (1983)
Chaetomorpha	crassa	Fo	**	Phillipines, Taiwan, China	Arasaki & Arasaki (1983)
	javinica	Fo	*	Indonesia	Davidson (1976)
	linum	Fo	*	Phillipines	Davidson (1976)
Cladophora	sp.	Fd	*	SE Asia	Rabanal & Trono 1983
Codium	cylindricum	Fo	*	Korea	Arasaki & Arasaki (1983)
	decorticatum	Fo	*	Caribbean	Michanek(1975)
	divaricatum	Fo	*	Korea, Japan	Arasaki & Arasaki (1983)
	edule	Fo	**	Hawaii	Arasaki & Arasaki (1983)
	fragile	Fo	**	Korea, Japan	Arasaki & Arasaki (1983)
	muelleri	Fo	*	Hawaii	Chapman & Chapman (1980)
	reediae	Fo	**	Hawaii	Arasaki & Arasaki (1983)
	tomentosum	Fo	*	Indonesia	Arasaki & Arasaki (1983)
Enteromorpha	clathrata	Fo	*	Japan, Taiwan, USA, China Tobago	Arasaki & Arasaki (1983)
	compressa	Fo	*	Japan, China	Chapman & Chapman (1980)
	flexuosa	Fo	*	Hawaii	Chapman & Chapman (1980)
	intestinalis	Fo	**	Japan, Phillipines, China Malaya, Hawaii	Arasaki & Arasaki (1983)
	linza	Fd	**	Japan	Arasaki & Arasaki (1983)
	prolifera	Fd	**	Hawaii, Japan, China	Arasaki & Arasaki (1983)
	sp.	Med.	*	Japan	Arasaki & Arasaki (1983)
Halimeda	sp.	Fd	*	SE Asia	Rabanal & Trono (1983)
Monostroma	latissima	Fo	**	Japan, Taiwan	Arasaki & Arasaki (1983)
	nitidum	Fo	*	Japan	Arasaki & Arasaki (1983)
Prasiola	japonica	Fo	*	Japan, Mexico	Arasaki & Arasaki (1983)
Ulva	fasciata	Fo	*	Hawaii, Japan	Arasaki & Arasaki (1983)
	faselata	Fd	*	Temperate-warmer Pacific Atlantic and Indian Oceans	Arasaki & Arasaki (1983)
	japonica	Fo	*	Korea	Arasaki & Arasaki (1983)
	lactuca	Fd, Med	**	Scotland, China, Phillipines Taiwan, Indonesia West Indies, Chile	Arasaki & Arasaki (1983)
	linza	Fo	*	West Indies	Chapman & Chapman (1980)
	pertusa	,Med	*	Japan, West Indies	Rabanal & Trono 1983
Nostoc	sp.	Fo	**	Japan, Sth America, China Malaysia	Madelener (1977)
			PHAEOPHYTA		
Alaria	crassifolia	Fo	*	Japan	Chapman & Chapman (1980)
	esculenta	Fo, Al, Fd	**	USA, Scotland, Orkney Is.s, Iceland, Korea, Alaska Greenland	Arasaki & Arasaki (1983)
Analipus	japonicus	Fo	**	Japan	Madelener (1977)
Arthrothamnus	bifidus	Fo, Al	**	Cold Nth Pacific	Arasaki & Arasaki (1983)
	kuilensis	Fo	*	Japan	Chapman & Chapman (1980)
	mackaii	Fo	*	USA	Chapman & Chapman (1980)
Ascophyllum	nodosum	Fert, Al, Fd	***	UK	EGM, Cullen (1988)
Chnoospora	pacifica	Fo	*	Vietnam, Guam	Chapman & Chapman (1980)
Chorda	filum	Fo	**	Japan	Madelener (1977)
Chordaria		Fo	*	Japan	Michanek(1975)
Cladosiphon	sp.	Fo	*	Japan	Saito (1976)

continued.

Genus	Species	Use	Value	Where Used	Reference
Cystophyllum	muricatum	Al	*	India	Michanek(1975)
Cystoseira	osmundacea	Al	**	Mexico, Nth America	Arasaki & Arasaki (1983)
Dictyopteris	plagigramma	Fo	**	Hawaii	Arasaki & Arasaki (1983)
Dictyota		Meal	*	Brazil	Michanek(1975)
Durvillaea	antarctica	Al	**	Chile	Arasaki & Arasaki (1983)
	potatorum	Fertilizer, Al	**	Australia	EGM, Cullen (1988)
Ecklonia	cava	Fo, Al	**	Japan, China	Arasaki & Arasaki (1983)
	stolonifera	Fo	*	Korea, Japan	Arasaki & Arasaki (1983)
Egregia	laevigata	Al	**	Pacific Nth America	Arasaki & Arasaki (1983)
Eisenia	arborea	Fo, Al	**	Nth Pacific	Arasaki & Arasaki (1983)
	bicyclis	Fo, Fd, Al,Fert., Med.	**	Japan	Arasaki & Arasaki (1983)
Endarachne	binghamiae	Fo	**	Japan	Arasaki & Arasaki (1983)
Fucus	evanescens	Al	**	Cold Atlantic & Pacific Coasts	Arasaki & Arasaki (1983)
	vesiculosus	Fo, Fd	**	W Europe, USA, Alaska	Madelener (1977)
Hedophyllum	sessile	Al	*	Nth America	Michanek(1975)
Heterochordaria	abietina	Fo	**	Japan	Arasaki & Arasaki (1983)
Himanthalia		Al	*	Brittany	Michanek(1975)
Hizikia	fusiforme	Fo	**	Japan, Korea, China	Arasaki & Arasaki (1983)
Hormophysa		Al	*	India	Michanek(1975)
Hydroclathrus	cancellatus	Fo, Fert	*	Phillipines, SE Asia	Arasaki & Arasaki (1983)
Kjellmaniela	crassifolia	Fo	*	Japan	Arasaki & Arasaki (1983)
	gyrata	Fo	**	Japan	Arasaki & Arasaki (1983)
Laminaria	angustata	Fo	**	Japan, USSR	Arasaki & Arasaki (1983)
	bongardiana	Fo	*	Alaska	Chapman & Chapman (1980)
	cichoriodes	Fo	*	USSR	Chapman & Chapman (1980)
	cloustonii	Al	**	Cold Atlantic	Arasaki & Arasaki (1983)
	coriacea	Fo	*	Japan	Arasaki & Arasaki (1983)
	diabolica	Fo	*	USSR	Chapman & Chapman (1980)
	digitata	Al	**	W Europe, Iceland, Nth America	Arasaki & Arasaki (1983)
	fragilis	Fo	**	USSR	Chapman & Chapman (1980)
	hyperborea	Iodine	*	Scotland	Michanek(1975)
	japonica	Fo, Med.	***	Japan, Korea, USSR	Arasaki & Arasaki (1983)
	longicruris	Fo	**	Nth America	Madelener (1977)
	longissima	Fo	**	Japan, China, USSR	Madelener (1977)
	ochotensis	Fo	**	Japan, China, USSR	Madelener (1977)
	religiosa	Fo	**	USSR	Arasaki & Arasaki (1983)
	saccharina	Fo, Al	**	China, Brittany, W. Europe	Arasaki & Arasaki (1983)
	sinclairii	Al	**	Pacific Coasts of North America	Arasaki & Arasaki (1983)
	yezoensis	Fo	*	USSR	Chapman & Chapman (1980)
Lessonia	flavicans	Al	**	Colder Southern Atlantic & Antarctic Oceans	Arasaki & Arasaki (1983)
Macrocystis	pyrifera	Fo, Al.	***	California	Madelener (1977)
Nemacystus	decipiens	Fo, Med.	**	Japan	Arasaki & Arasaki (1983)
Nereocystus	luetekeana	Al	**	Alaska, USA	Arasaki & Arasaki (1983)
Padina	australis	Fo	*	SE Asia	Chapman & Chapman (1980)
	commersonnii	Al	*	India	Michanek(1975)
	tetrastromatica	Fo	*	Sri Lanka	Michanek(1975)
Pelvetia	canaliculata	Al	**	Cold Pacific & Atlantic Coasts	Arasaki & Arasaki (1983)
Petalonia	fascia	Fo	**	Japan	Madelener (1977)
Pleurophycus	gardneri	Fo	*	USA	Madelener (1977)
Pocockiella		Al	*	India	Michanek(1975)
Postelsia	palmaeformis	Fo, Al	*	California	Madelener (1977)
Sacchorhiza	polyschides	Fo, Al, Iodine	**	Cold Atlantic	Arasaki & Arasaki (1983)
Sargassum	confusum	Fo	*	Japan	Arasaki & Arasaki (1983)
	echinocarpum	Fo	**	Hawaiian Islands, SE Asia	Arasaki & Arasaki (1983)
	enerve	Fo	*	Japan	Chapman & Chapman (1980)
	fulvellum	Fo, Al	**	Korea, Japan	Arasaki & Arasaki (1983)
	fusiformis	Fo	*	China	Arasaki & Arasaki (1983)

continued.

Genus	Species	Use	Value	Where Used	Reference
	horneri	Fert	*	China, Korea	Michanek(1975)
	sagamianum	Fo	*	Korea	Michanek(1975)
	serratifolium	Fo	*	China	Chapman & Chapman (1980)
	sinctum	Fo	*	Vietnam	Michanek(1975)
	thunbergii	Med.	*	Japan	Arasaki & Arasaki (1983)
Scytosiphon	lomentaria	Fo	**	Japan	Arasaki & Arasaki (1983)
Tinocladia	crassa	Fo	*	Japan	Arasaki & Arasaki (1983)
Turbinaria	sp.	Fo, Al	**	Indonesia	Rabanal & Trono 1983
Undaria	peterseniana	Fo	**	Temperate Japan	Arasaki & Arasaki (1983)
	pinnatifida	Fo, Med.	**	Japan, Korea, China	Arasaki & Arasaki (1983)
				RHODOPHYTA	
Acanthopeltis	japonica	Ag	**	Japan	Arasaki & Arasaki (1983)
Acanthophora	specifera	Fo, Ca.	**	Indonesia	Arasaki & Arasaki (1983)
Aeodes	orbitosa	Ca ?	*	Sth Africa	Chapman & Chapman (1980)
	ulvoidea	Ca ?	*	Sth Africa	Chapman & Chapman (1980)
Agardhiella	sp.	Fo	*	Phillipines	Davidson (1976)
Ahnfeltia	concinna	Fo	*	Hawaii	Arasaki & Arasaki (1983)
	gigartinoides	Fo, Ag	**	Hawaii, USSR, Japan	Arasaki & Arasaki (1983)
	paradoxa	Ag	**	Japan	Arasaki & Arasaki (1983)
	plicata	Ag	**	USSR	Arasaki & Arasaki (1983)
Alsidium	helminthocarton	Med.	*	Japan	Arasaki & Arasaki (1983)
Asparagopsis	sandfordiana	Fo	*	Hawaii	Arasaki & Arasaki (1983)
	taxiformis	Fo	**	Hawaii, Indonesia, Java	Arasaki & Arasaki (1983)
Bangia	fusco-purpurea	Fo	*	Japan, China, Taiwan	Arasaki & Arasaki (1983)
Bostrychia	radicans	Fo	*	Burma	Davidson (1976)
Brongniartella	mucronata	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
Bryothamnion	seaforthii	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	triquetrum	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
Caloglossa	sp.	Fo	*	Burma	Davidson (1976)
Camplyaeophora	hypnaeoides	Fo, Ag	*	Japan	Arasaki & Arasaki (1983)
Carpopeltis	affinis	Fo	*	Japan	Chapman & Chapman (1980)
	flabellata	Fo	*	Japan	Chapman & Chapman (1980)
	formosana	Fo	*	Botel Tobago Is.	Hansen et al(1981)
Catenella	impudica	Fo	*	Burma	Davidson (1976)
	nipae	Fo	*	Burma	Arasaki & Arasaki (1983)
Ceramium	boydenii	Ag	**	Cold Temperate Waters, NW Pacific	Arasaki & Arasaki (1983)
	kondoi	Adh. Paste, Ag	*	Japan	Arasaki & Arasaki (1983)
Chondria	armata	Insecticide	*	Japan	Arasaki & Arasaki (1983)
Chondrus	crispus	Med., Ca, Fo	***	E. USA, Iceland, France	Arasaki & Arasaki (1983)
	elatus	Ca	**	Japan, China	Arasaki & Arasaki (1983)
	ocellatus	Fo, Adh. Paste	**	Japan	Arasaki & Arasaki (1983)
	yendoi	Fo, Ca	**	Japan	Arasaki & Arasaki (1983)
Corallina	officianalis	Med.	*	Japan	Arasaki & Arasaki (1983)
	reibens	Med.	*	Japan	Arasaki & Arasaki (1983)
	squamata	Med.	*	Japan	Arasaki & Arasaki (1983)
Corallopsis	minor	Fo	*	Indonesia	Arasaki & Arasaki (1983)
	salicornia	Fo	*	Indonesia	Chapman & Chapman (1980)
Delisea		Ca ?	*	?	Chapman & Chapman (1980)
Dermonema	gracile	Fo	*	Botel Tobago Is.	Hansen et al(1981)
Dignea	simplex	Fo, Ag Insecticide	*	Japan, SE Asia	Arasaki & Arasaki (1983)
Dumontia	incrassata	Ca ?	*	?	Chapman & Chapman (1980)
Enantiocladia	duperreyi	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
Endocladia		Ca	*	?	Chapman & Chapman (1980)
Euchema	cottonii	Ca	**	SE Asia, Phillipines	Chapman & Chapman (1980)
	edule	Fo	*	China	Arasaki & Arasaki (1983)
	gelatinae	Fo, Ca	**	China	Arasaki & Arasaki (1983)
	isiforme	Fo	*	Antigua, Barbados	Chapman & Chapman (1980)
	muricatum	Fo, Ca	**	Japan	Arasaki & Arasaki (1983)
	nudum	Fo, Ca	*	West Florida & Bermuda	Arasaki & Arasaki (1983)

continued.

Genus	Species	Use	Value	Where Used	Reference
	papulosa	Fo	*	China	Chapman & Chapman (1980)
	serra	Ca	*	Far East, East Africa	Chapman & Chapman (1980)
	speciosum	Fo, Ag	*	Western Australia	Michanek(1975)
	spinosum	Ca	*	Phillipines, China	Chapman & Chapman (1980)
	striatum	Ca	*	Tanzania	Michanek(1975)
	uncinatum	Ca	*	Mexico	Chapman & Chapman (1980)
Furcellaria	fastigiata	Ca ?	*	Denmark, Russia, Canada	Chapman & Chapman (1980)
Gelidiella	acerosa	Ag	**	Japan	Chapman & Chapman (1980)
Gelidiopsis	rigida	Fo, Ag	*	Indonesia, Phillipines	Arasaki & Arasaki (1983)
Gelidium	amansii	Ag	***	Japan, China, Indonesia, Taiwan, Korea	Arasaki & Arasaki (1983)
	arborescens	Ag	**	Central California	Arasaki & Arasaki (1983)
	attenuatum	Ag	*	Portugal	Michanek(1975)
	cartilagineum	Ag	***	S. Africa, California, Mexico	Arasaki & Arasaki (1983)
	corneum	Ag	**	Spain, Portugal, Morocco, California, Cuba	Chapman & Chapman (1980)
	decumbensum	Ag	*	Japan	Arasaki & Arasaki (1983)
	densum	Ag	*	California	Chapman & Chapman (1980)
	divaricatum	Fo	*	Japan, China, Korea	Chapman & Chapman (1980)
	japonicum	Ag	**	Japan, Korea, China	Arasaki & Arasaki (1983)
	latifolium	Ag	**	Atlantic Ocean	Arasaki & Arasaki (1983)
	liatulum	Ag	**	Japan, Korea, China	Chapman & Chapman (1980)
	lingulatum	Ag	*	Chile	Chapman & Chapman (1980)
	nudifrons	Ag	*	California	Chapman & Chapman (1980)
	pacificum	Ag	**	Japan, Korea, China	Arasaki & Arasaki (1983)
	pristoides	Ag	**	Sth Africa	Chapman & Chapman (1980)
	sesquipedale	Ag	**	Portugal	Chapman & Chapman (1980)
	spinulosum	Ag	**	Morocco	Chapman & Chapman (1980)
	subcostatum	Ag	**	Japan, Korea, China	Arasaki & Arasaki (1983)
	subfastigiatum	Ag	*	Japan, Korea, China	Chapman & Chapman (1980)
	vagum	Ag	*	Japan, Korea, China	Chapman & Chapman (1980)
	acicularis	Ca	**	Sth Europe, Morocco	Chapman & Chapman (1980)
	canaliculata	Ca	*	Mexico	Chapman & Chapman (1980)
	chamissoi	Ca	*	Chile	Chapman & Chapman (1980)
	exasperata	Fo, Ca	**	Pacific Coast of North America.	Arasaki & Arasaki (1983)
	mamillosa	Ag	*	Japan	Arasaki & Arasaki (1983)
	papillata	Fo	*	Iceland	Madelener (1977)
	pistillata	Ca	*	Sth Europe, Morocco	Chapman & Chapman (1980)
	radula	Ca	*	Sth Africa	Chapman & Chapman (1980)
	scottsbergii	Ca	*	Sth Europe, Morocco	Chapman & Chapman (1980)
	stellata	Ca	*	SE Asia, Ireland	Arasaki & Arasaki (1983)
	teedii	Fo	*	Japan	Chapman & Chapman (1980)
	tenella	Ag	*	Japan	Arasaki & Arasaki (1983)
Gloiopeltis	coliformis	Fo	*	Nth China	Chapman & Chapman (1980)
	furcata	Fo	**	Japan, Vietnam, China	Arasaki & Arasaki (1983)
	sp.	Ag ?	*	?	Chapman & Chapman (1980)
	tenax	Fo	*	Taiwan, China	Chapman & Chapman (1980)
Gracilaria	caudata	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	cervicornis	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	compressa	Fo	*	England, Wales	Chapman & Chapman (1980)
	confervoides	Fo	**	Thailand	Davidson (1976)
	cornea	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	coronopifolia	Fo	**		Arasaki & Arasaki (1983)
	crassa	Fo, Ag	**	Hawaii, SE Asia	Arasaki & Arasaki (1983)
	crassissima	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	cylindrica	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	damaecornis	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	edulis	Ag	*	Japan	Arasaki & Arasaki (1983)
	ferox	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	follifera	Fo	**	Gulf of Mexico, Cuba	Arasaki & Arasaki (1983)
	lichenoides	Fo	*	Indonesia, Ceylon	Arasaki & Arasaki (1983)
	ligulata	Fo	*	China	Arasaki & Arasaki (1983)
	mamillaris	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)

continued.

Genus	Species	Use	Value	Where Used	Reference
	multipartita	Ag	*	Atlantic, Nth America	Chapman & Chapman (1980)
	taenoides	Fo	*	Indonesia	Arasaki & Arasaki (1983)
	textorii	Fo, Ag	**	Japan, Java, Indonesia	Arasaki & Arasaki (1983)
	verrucosa	Fo, Ag	***	Japan, Vietnam, California, Malaysia, Sth Africa, Phillipines, Ceylon, China	Arasaki & Arasaki (1983)
Gracilariopsis	sjoestedtii	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
Grateloupia	divaricata	Ag	*	Japan	Arasaki & Arasaki (1983)
	doryphora	Fo	**	SE Asia	Arasaki & Arasaki (1983)
	filicina	Adh. Paste	*	Japan, Hawaii, China	Arasaki & Arasaki (1983)
	turuturu	Ag	*	Japan	Arasaki & Arasaki (1983)
Griffithsia	corallina	Fo	*	Vietnam	Davidson (1976)
Gymnogongrus	flabelliformis	Fo	*	Japan	Arasaki & Arasaki (1983)
	javinicus	Fo	*	Indonesia	Arasaki & Arasaki (1983)
	tenuis	Ag	*	Cuba, Puerto Rico	Chapman & Chapman (1980)
	vermicularis	Fo	*	Hawaii	Chapman & Chapman (1980)
Haliseris		Fo	*	Hawaii	Michanek(1975)
Halosaccion	glandiforme	Fo	*	USSR	Madelener (1977)
	ramentaceum	Fo	*	Labradour	Michanek(1975)
Halymenia	durvillaei	Fo	*	Botel Tobago Is.	Hansen et al(1981)
	sp.	Fo	*	SE ASia	Rabanal & Trono 1983
Hypnea	cervicornis	Fo, Ca	*	Indonesia, China	Arasaki & Arasaki (1983)
	charoides	Ca ?	*	Japan, Cuba	Arasaki & Arasaki (1983)
	musciformis	Ag ?	**	Brazil, Senegal, Phillipines, Cuba	Chapman & Chapman (1980)
	nidifica	Fo	*	Hawaii	Chapman & Chapman (1980)
Iridaea	edulis	Fo	*	Scotland, Iceland	Chapman & Chapman (1980)
	radula	Ca	**	SE Asia	Chapman & Chapman (1980)
Iridophycus	sp.	Ca	*	?	Chapman & Chapman (1980)
Laurencia	nidifica	Fo	*	Hawaii	Arasaki & Arasaki (1983)
	obtusa	Fo	*	Indonesia	Arasaki & Arasaki (1983)
	papliiosa	Fo	*	Phillipines	Michanek(1975)
	pinnatifida	Fo	*	USA, W Europe, Scotland	Chapman & Chapman (1980)
Liagora	sp.	Fo	*	SE Asia	Rabanal & Trono 1983
Lithothamnion	calcerum	Fert	*	France	Michanek(1975)
Meristotheca	papulosa	Fo	**	Japan	Arasaki & Arasaki (1983)
Mesogloia	decipiens	Fo	*	Japan	Chapman & Chapman (1980)
Naias	sp.	Fo	*	Hawaii	Michanek(1975)
Nemalion	helminthoides	Fo	*	Japan, Italy	Chapman & Chapman (1980)
	multifidum	Fo	*	Japan	Chapman & Chapman (1980)
	vermiculare	Fo	*	Japan	Chapman & Chapman (1980)
Pachymenia	carnosa	Ca ?	*	Sth Africa	Chapman & Chapman (1980)
Pachymeniopsis	sp.	Adh Paste	*	Japan	Saito (1976)
Palmaria	palmata	Fo	**	E USA, E Canada, Alaska, Brittany, Ireland, Iceland, W Europe, USSR, Mediterranean	Arasaki & Arasaki (1983)
Peyssonnelia	capensis	Ag	*	Angola	Michanek(1975)
Phyllophora	nervosa	Ca	**	Black Sea	Mc Hugh & Lanier 1983
	rubens	Ca	**	Black Sea	Mc Hugh & Lanier 1983
Polyneura	latissima	Fo	*	California, Phillipines	Madelener (1977)
Porphyra	angustata	Fo	**	Japan	Chapman & Chapman (1980)
	columbina	Fo	*	Chile	Chapman & Chapman (1980)
	crispata	Fo	**	SE Asia, Japan	Arasaki & Arasaki (1983)
	dentata	Fo	**	Japan, China	Arasaki & Arasaki (1983)
	kunieda	Fo	**	Japan	Chapman & Chapman (1980)
	laciniata	Fo	*	Europe, Alaska	Chapman & Chapman (1980)
	miniata	Fo	*	Vancouver, British Columbia, Puget Sound	Chapman & Chapman (1980)
	nereocystis	Fo	**	USA	Arasaki & Arasaki (1983)
	okamurai	Fo	**	Japan	Chapman & Chapman (1980)
	onoi	Fo	**	Japan	Chapman & Chapman (1980)
	perforata	Fo	**	W USA	Arasaki & Arasaki (1983)
	pseudolinearis	Fo	**	Japan	Arasaki & Arasaki (1983)
	serieta	Fo	**	Japan	Chapman & Chapman (1980)

continued.

Genus	Species	Use	Value	Where Used	Reference
	sp.	Med.	*	Japan	Arasaki & Arasaki (1983)
	suborbiculata	Fo	**	Japan, China, Korea, USA, Hong Kong	Arasaki & Arasaki (1983)
	tenera	Fo	***	Japan, China, Korea	Arasaki & Arasaki (1983)
	umbilicalis	Fo	**	Japan, Scotland, Ireland, Wales	Arasaki & Arasaki (1983)
	yezoensis	Fo	***	Japan	Arasaki & Arasaki (1983)
Pterocladia	americana	Ag	**	Warm N America, W Florida, Bermuda.	Arasaki & Arasaki (1983)
	capillacea	Ag	**	N.Z., Azores, Japan, USA	Arasaki & Arasaki (1983)
	densa	Ag	*	Japan	Chapman & Chapman (1980)
	lucida	Ag	**	Australia, NZ	Chapman & Chapman (1980)
	pinnata (capillacea)	Ag	**	Japan, NZ, USA	Chapman & Chapman (1980)
	pyramidale	Ag	**	East Pacific	Arasaki & Arasaki (1983)
	tenuis	Ag	*	Japan ?	Arasaki & Arasaki (1983)
Rhodoglossum	lanceolatum	Ca ?	*	Japan ?	Austrade
Rhodymenia	palmata	Fo, Fd	*	Europe, Nth America	Michanek(1975)
Sarcodia	ceylanica	Fo	*	Japan	Chapman & Chapman (1980)
	montagneana	Fo	*	Indonesia	Arasaki & Arasaki (1983)
Sarconema	sp.	Ag	*	India	Michanek(1975)
Scinaia	sp.	Fo	*	SE Asia	Rabanal & Trono 1983
Spyridia		Ag	*	India	Michanek(1975)
Suhria	vittata	Ag ?	*	Sth Africa	Chapman & Chapman (1980)
Tichocarpus	crinitus	Ca	*	USSR	Chapman & Chapman (1980)
Turnerella	sp.	Adh Paste	*	Japan	Saito (1976)
Yatabella		Ca	*	?	Chapman & Chapman (1980)

APPENDIX 2 Value of the Japanese Yen (¥) and the American Dollar against the Australian Dollar.

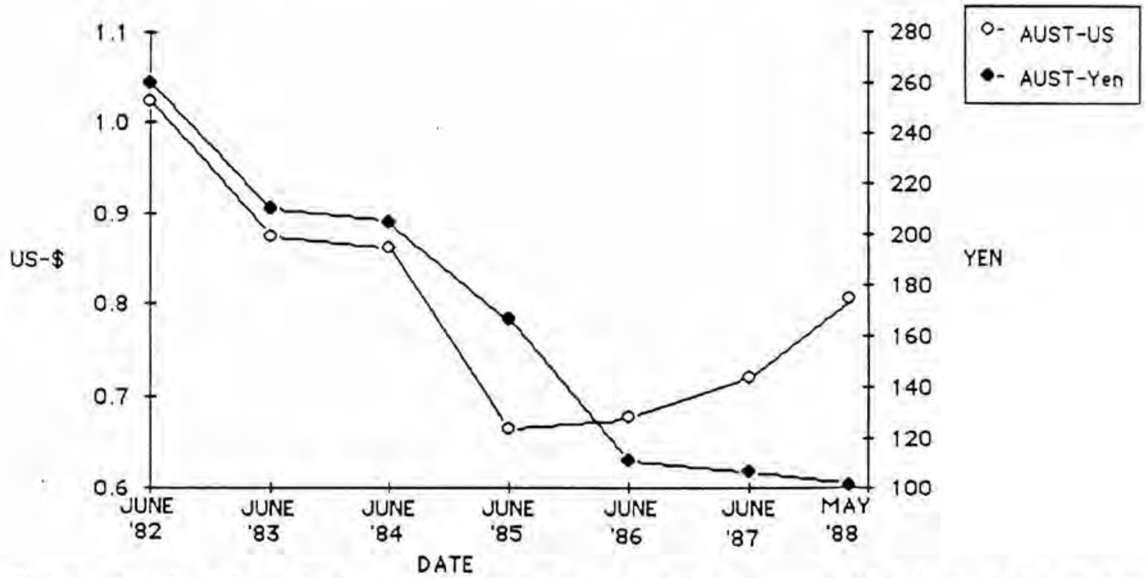

Figure showing the value of the Aust-$ in US-$ and Japanese Yen from 1982 to the present. Values are taken from the Reserve Bank Bulletin and are those at the close of trading (4-pm.) on the last day of the month in question.